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Deterioration in the performance of a line-of-sight link at 7.3 GHz located in Indian dry southern region

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Abstract : The deteriorated performance of a communication link operating at 7.338 GHz situated between Gooty and Penukonda and located in the Indian dry southern region has been investigated. The non performance of the link in terms of months and time have been determined. It has been seen that under normal condition the field strength was usually of the order of –60 dBm. The link performance started deteriorating when the signal level reduced as low as around –75 dBm and the link was found not to serve any purpose when the field strength level was below –75 dBm. The observations on field strength were obtained from an operational agency when there was deterioration in the link performance. The problematic months are found to be from January to May. The peak problematic month for this link is March. The effects of meteorological conditions on the deteriorated performance have also been identified. Multipath fading caused due to stratified layers in the lower atmosphere is responsible for low field strength. In order to counter the multipath fading, the remedial technique such as antenna tilting may be deployed or the system should be equipped with some diversity in order to have the best of the received signals. Such type of study has two fold of importance. Firstly it provides the causes for the deterioration in the performance of links. Secondly, this sort of study can form the basis for the future installation of links in Indian dry environmental region. The investigation also suggests that all future link should be equiped with some diversity system to overcome the deteriorated performance whenever it is there.

Keywords : Link, deterioration, peak period, layers, fall in temperature, multipath fading, diversity, antenna tilting

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1. Introduction

Line of sight terrestrial communication links operating in VHF and microwave frequency bands are affected by ground characteristics and meteorological conditions prevailing around link site [1–3]. In line of sight propagation, two types of fading are mainly observed [4]. One is scintillation fading and the other is multipath fading. Scintillation fading is usually caused due to the fluctuations of refractive index of the medium. Such fading is fast and characterized with low fades (1–2 dB). The multipath fading is caused due to interferences of the rays scattered/reflected from the atmospheric irregularities/layers, rays reflected from the ground, direct rays *etc.* The deterioration of the performance of a link is mainly caused by multipath fading [5]. The deteriorated performance of a communication link operating at 7.338 GHz situated between Gooty and Penukonda and located over Indian dry southern region has been investigated. It is usually seen that the field strength under normal condition is around –60 dBm. It is also seen that the purpose of the communication link is served when the field strength is more than –74 dBm. It has been found that the link serves no purpose for which it is used when field strength reduces to less than –75 from normal field strength (–60 dBm). The performance of the link has been found to be worst when the field strength is –80 dBm.

However, it is interesting to note that even low field strength is found to be associated with low fade depth (1–3 dB), moderate fade depth (5–10 dB) and large fade depth (10–20 dB). The meteorological conditions prevailing around the link site have been deduced from the ground based meteorological observations and the radiosonde data. It has been that the temperature inversion is formed due to the fall of ground temperature and variation of humidity. The temperature inversion is one of the main causes for the formation of super-refraction and ducting phenomena (stratified atmosphere). The multipath fading is found to be more under calm situation. The super refraction and ducting situations are also found to be more under calm weather. The performance deterioration of the link is due to the fall of signal level. The loss of signal can be achieved either by introducing some diversity system or the multipath fading effect can be reduced by employing some remedial techniques such as antenna tilting [5,6].

System and Terrain characteristics :

The field strength observations were obtained from an operational agency. The field strength measurements were made during 1992–97 by using a radio link situated between Gooty and Penukonda operating at 7.338 GHz with vertical polarization. The transmitted power is 1 watt receiver sensitivity –90 dBm with fade margin 30 dB. The transmitting antenna gain is 43 dB and the receiver antenna gain is also 43 dB. The free space loss over the path is 151 dB.

The terrain profile between Gooty and Penukonda is shown in Figure 1. The transmitting end is located at Gooty and the receiving end is at Penukonda. The terrain

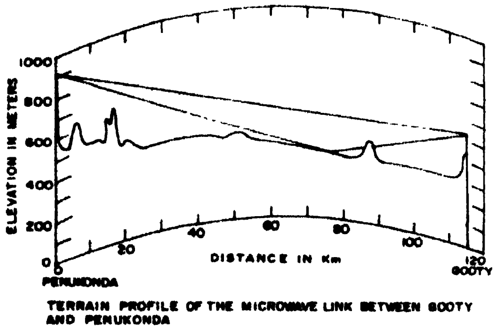

Figure 1. Terrain profile between Penukonda and Gooty.

consists of some hill tops around Penukonda. Beyond 20 km from Penukonda the terrain consists of rolling plains right upto Gooty. Penukonda is situated at an altitude of 917 m above mean sea level while Gooty is situated at an elevation 457 m above mean sea level. The path distance between the transmitting and receiving end is 115 km. The height of transmitting and receiving antenna is 80 m and 8 m from the ground.

Source of radio link observations and meteorological data :

The field strength measurements were taken by an operational agency and was provided to us to investigate the peak period of deterioration and the causes of deterioration in the link performance. The observations of field strength taken during the period of deterioration were provided to us.

The ground based meteorological observations and radiosonde data around the link site were obtained from the India Meteorological Department. The averaged meteorological condition was deduced on the basis of ground based meteorological measurements and radiosonde observations.

Data analysis, results and discussions :

The signal level larger than –75 dBm is considered to be good for any communication radio link performance wise. The performance of the link situated between Gooty and Penukonda has been found to be affected only when the signal level is equal to or less than –75 dBm. The non performance of the link has been determined by processing the measured signal levels when the signal levels are equal and less than –80 dBm. The carrier intensity was recorded during January to December. The performance of the link is found to be excellent during June to December. The link showed deterioration in the performance during January to May which are considered to be problematic months in the present study. The total duration during which the field strength is equal or less than –80 dBm in different months are shown in Figure 2. It is shown in Figure 2 that the field strength was equal or less than –80 dBm for 135 hrs, 105 hrs, 162 hrs, 70 hrs and 60 hrs in January, February, March, April and May respectively.

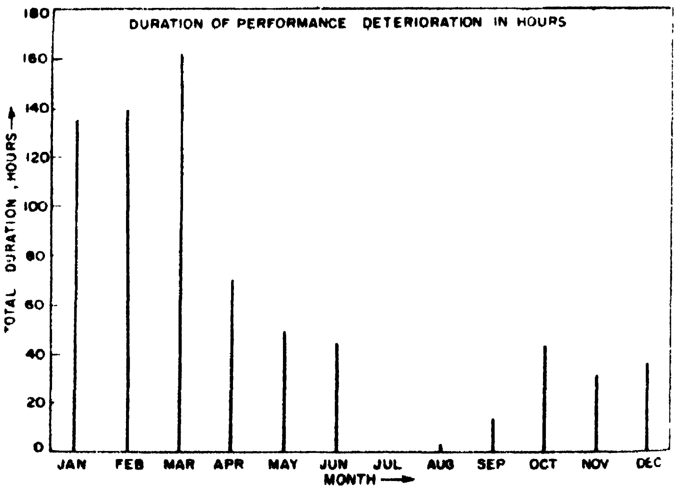

Figure 2. Total duration in different months when field strength was less than –80 dBm.

The number of days during which the performance of the link was not upto the mark and the signal was characterised with low field strength is shown in Figure 3. It is seen in Figure 3 that the low field strength was observed for 37 days, 30 days, 50 days, 24 days and 23 days in January, February, March, April and May.

The diurnal variation of the low signal when there was deterioration in the performance of the link and the received signal level as recorded was equal or less than –80 dBm is shown in Table 1. It is seen in Table 1 that the low signal level was observed more times during 0300 hrs–1000 hrs in January, February and March and low field strength was observed moderate times during 0000 hrs–1000 hrs in April and May. The low field strength was characterised for maximum period during 0400 hrs–1000 hrs in March. The maximum fading of the order of 15–20 dB was observed during January, February and March and the fading was of moderate order 5–10 dB in November and December during 0000 hrs–1000 hrs.

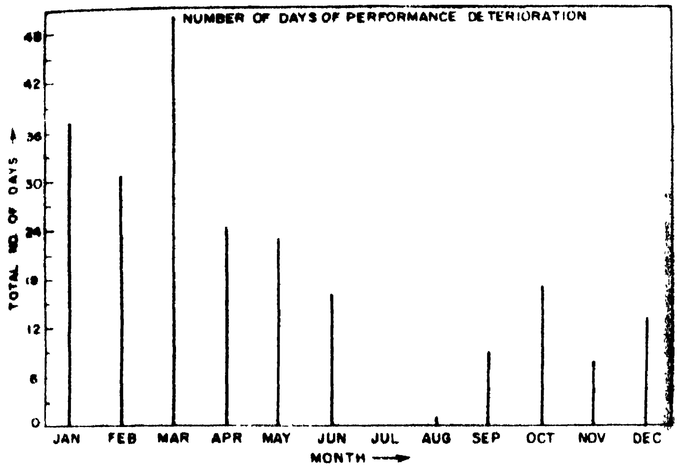

Figure 3. Number of days in a month when there was deterioration in the link performane.

Table 1. Performance deterioration in relation to number of days in a month during different time.

Time in hours IST	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
06–07	19	11	26	13	9	4	–	1	–	3	5	4
07–08	25	17	28	15	10	3	-	1	1	4	4	5
08–09	22	19	29	13	5	2	–	–	4	5	5	6
09-10	20	12	24	2	2	1	–	–	–	5	5	2
10-11	4	–	2	–	1	1	–	–	–	1	–	1
11 12	–	–	–	–	–	–	–	–	–	1	–	–
12–13	–	–	–	–	–	–	–	–	–	–	–	–
13–14	–	–	–	–	–	–	–	–	–	–	–	–
14–15	–	–	–	–	–	–	–	–	–	–	–	–
15–16	–	–	–	–	–	–	–	–	–	–	–	–
16–17	–	–	–	–	–	–	–	–	–	1	–	–
17–18	–	–	–	–	–	1	–	–	–	–	–	–
18-19	–	–	–	–	1	1	–	–	–	–	–	1
19–20	–	–	–	–	2	2	–	–	1	1	–	–
20–21	–	–	1	–	2	3	–	–	1	1	–	–
21-22	–	–	–	–	1	2	–	–	2	1	1	–
22-23	–	1	–	–	1	3	–	–	–	2	1	–
23–00	2	2	–	–	–	3	–	–	2	1	1	–
00-01	6	4	2	1	5	4	–	–	3	3	1	3
01–02	7	4	5	4	6	3	–	–	2	3	1	4
02–03	9	7	8	5	4	3	–	–	1	1	1	5
03–04	11	10	13	8	1	4	–	–	1	4	2	4
04–05	13	11	19	10	4	5	–	–	1	5	4	2
05–06	16	4	22	9	7	5	–	1	–	4	4	3

The fade depths deduced from the measured field strength observations and its association with various percentage levels are presented in Table 2. A fade is defined in this study as the difference of the maxima and minima of an instantaneous signal level. More precisely, it is the difference of the two ends of a signal level. Here, the fade depth has been determined when the signal level is of low order *i.e.*, one end of the signal level is equal or less than –80 dBm. For example, suppose the signal level has varied from –70 dBm to –80 dBm, it indicates that the fade depth is (–70 dBm – (–80 dBm)) = 10 dB. It is seen that large fades of the order of 10 dB is found to occur for around 30% of the time while 16 dB has been found to occur for 10% of the time. The present operating radio system has been provided fade margin 30 dB. The present link performance is not affected due to fade depths but the problem in the

Table 2. Distribution of fade depth associated with low signal level

Percentage level dB	Fade depth
5	18
10	16
20	13
30	10
50	7
60	6
70	5
90	4
99.99	2

Table 3. Ground based meteorological conditions around link site.

Month		Temp.	Fall of temp. °C	Rel. humidity %	Fall of rel. humidity %
Jan	I	21	8	69	33
	II	29		36	
Feb	I	23	9	54	28
	II	25		26	
Mar	I	26	9	47	28
	II	35		19	
Apr	I	29	8	52	29
	II	37		23	
May	I	29	7	62	30
	II	36		32	

I corresponds to 0530 hrs IST observations.
II corresponds to 1730 hrs IST observations.

performance of the link arises when signal becomes low. The meteorological characteristics around the radio path deduced from the ground based observations is presented in Table 3. It is seen that the fall of temperature from daytime to nighttime is appreciable durıng January to May when there is deterioration in the performance of the link. The fall in temperature is maximum around 8°C to 9°C in the month of March. The deterioration in the link performance has also been found to be maximum in March. The fall of ground temperature is responsible for thr cooling of the earth's surface due to radiative nocturnal cooling. The radiative cooling causes temperature inversion and hence produces stratified situations in the atmosphere with high refractivity gradient. The degree of stratification increases when the refractivity gradient is of large order. The large order of degree of stratification supports atmospheric layers formation. It has been observed by acoustic sounder that ground based and elevated layers are found for significant percentage of time in this region [7]. The radio rays travel through different paths through these layers. It has been seen whenever there is defocussing effect there is fall in signal level [8,9]. The radio rays travelling through different paths under such stratified atmospheric situations give rise to fades which is termed as multipath fading. The observed fall of ground temperature from day to night in April and May are 7°C–8°C. The fall of temperature in other months when there is no problem with the performance of the link is of low order 3°C. The ground based ducting frequency and super refraction frequency across 0.5 km–1 km around the radio link have been determined. The radiosonde observations are also taken at 0.5 km and 1 km. These observations have been analysed to obtain the ducting and super refraction occurrence frequency for different months. Such results have been deduced around the link location on the basis of the radiosonde observations taken from the nearest available radiosonde stations. In order to do so the local meteorological conditions prevailing around and over the link location and other nearest radiosonde stations from the link site have also been considered. The superrefractive and ducting conditions have been found to be more in January, February, March, April and May. The average refractivity gradient of the five months (January–May) has been found to be –60 N/km. The radio refractivity gradient of the order of –40 N/km is considered for standard atmosphere. The refractivity gradient around –60 N/km is considered to be high and is a favourable condition for multipath fading. The superrefractive and ducting frequency are 10% and 12% during March when the deterioration in the link performane is maximum due to multipath fading.

A system should be equiped with some diversity systems so that the best of the signal can be utilised. The frequency diversity and space diversity are the most common and easily available diversity techniques. But, in case of the space diversity, vertically space diversity is more effective. In order to counter the atmospheric effects such as multipath fading antenna tilting technique may also be utilised. In case of antenna tilting, contribution from ground reflections is minimised so that maximum contributions are made to available from direct rays thus reducing multipath fading. The antenna tilting experiment should be tried (tilting) with both antennas wherever there is problem in the link. The antennas should be fixed whereever maximum signal is achieved.

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